LOCKE

Density & Strength of
Portland Cement Mortar

Civil Engineering

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DENSITY AND STRENGTH OF PORTLAND CEMENT MORTAR

BY

WALTER COUTANT LOCKE

THESIS

For the Degree of

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WALTER COUTANT LOCKE

ENTITLED DENSITY AND STRENGTH OF PORTLAND CEMENT MORTAR

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

J. J. Richey
Instructor in Charge

APPROVED: John P. Brooks

HEAD OF DEPARTMENT OF Civil Engineering

DENSITY AND STRENGTH OF PORTLAND CEMENT MORTAR.

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INTRODUCTION.

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Engineers are recognizing more and more, the inconsistency of formulating a very elaborate set of standard specifications for Portland cement, and then making no definite requirements in regard to the sand to be used, except that it shall be clean and sharp. It is a fact worth emphasizing that the strength of cement mortar is dependent on the sand as well as the cement. There should be a careful and systematic inspection and testing of the sand as well as of the cement, on all important construction. It is therefore desirable to formulate standard specifications for sand and standard methods of testing sand, similar to those now adopted for testing cement. Sand forms by far the greatest portion of the mortar, and therefore it is desirable that the sand be the best obtainable.

Experiments made in Little Falls, New Jersey, in 1901, by William B. Fuller and Sanford E. Thompson, upon the strength and density of concrete beams mixed in various proportions by weight, indicate that the strength of concrete varies with the density, and also with the percentage of cement. With the same percentage of cement in a given volume of concrete,

the densest mixture was the strongest. The tests further indicated that , for the material used, there was a certain mixture of sizes of grains of the aggregate which gave the highest breaking strength. If the above be true, it is possible to make a mixture of maximum density, by making the volumetric or density tests, which mixture will give the maximum breaking strength.

Mr. R. Feret, in his tests upon mortars, has arrived at some conclusions which make the foregoing assumption at least probable. His conclusions may be stated as follows:(1) Coarse sand produces stronger and usually more impervious mortar than fine sand.(2) Fine sand requires more water than coarse sand, to produce a mortar of like consistency, and consequently the mortar is less dense. (3)Mixtures of fine and coarse sand produce stronger mortar than either material alone. (4) Sands for maximum density are composed of a mixture of fine and coarse grains, with no intermediate grains.

The first three of the above conclusions agree with those established by Fuller and Thompson, while the fourth does not agree with their conclusions. For this thesis four artificially graded sands were investigated and conclusions relative to the grading and density for maximum strength were formulated. Several sands in their natural grading were also investigated and conclusions were arrived at relative to the sands.

DESCRIPTION.

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Several experiments were made to test the applicability to Portland cement mortars of the conclusions of Messrs. Fuller and Thompson, in regard to concrete. Four mixtures of cement and different artifically graded sands were tested for density by measuring the volume resulting from a definite weight of the corresponding materials. The volumetric test was also made on several mixtures of cement and natural sands. By natural sand is meant a sand just as taken from its natural bed. A comparison was then made with the tensile and the compressive strengths of briquettes and cubes, respectively, made from similar mixtures.

A definite combination of sizes was used in each of the artifically graded sands, and a constant maximum size of sand and percent of cement were maintained throughout the tests. The percentage of water required to obtain a soft mushy mixture of medium wet consistency was determined for each sand in the density tests, and water was used in the same proportion when mixing the mortar for the cubes and the briquettes.

The sand portions of the mixtures investigated were composed of various sized particles, from the finest to the maximum size used. The percentages of the various sizes for the natural sands were determined by mechanical analysis. Mechanical analysis may be defined as the process of separating the particles or grains of a material into the various sizes of

which it is composed, so that the material may be represented by a curve, each of whose ordinates is the percentage of the weight of the total sample which passes a sieve having holes of a diameter represented by the distance of this ordinate from the origin of the curve. The percentages of the various sizes for the artifically graded mixtures were determined graphically from the curves shown in Plate I. Fuller and Thompson in their experiments concluded that the mixture of sizes of particles of aggregate for concrete which appeared to give best results, gave for its mechanical analysis a curve approaching a parabola with its beginning at zero of coordinates, and passing through the upper end of the coarsest stone curve.

The object of a mechanical analysis curve, referred to above, are summed up as follows by Messrs. Fuller and Thompson.

(a) "To show graphically the sizes and relative sizes of the particles."

(b) "To indicate what sized particles are needed to make the aggregate more nearly perfect, and so enable the engineer to improve it by the addition or substitution of another material."

(c) "To afford means for determining the best proportions of different aggregates."

MATERIALS.

Cement.

Chicage A A Portland cement was used throughout the tests. Before being used it was run through a No. 10 sieve to remove coarse particles. The Specific Gravity was found to be 3.15

TABLE 1

SHOWING THE TENSILE STRENGTH OF NEAT PORTLAND CEMENT.

AGE DAYS.	BREAKING LOAD LBS. PER SQ. INCH.
28	600
"	610
"	580
"	650
"	665
"	630
AVERAGE	623
90	750
"	775
"	775
"	770
"	760
"	740
AVERAGE	762

TABLE 2

SHOWING THE MECHANICAL ANALYSIS OF NEAT PORTLAND CEMENT.

SIEVE No.	PERCENT RETAINED.	PERCENT PASSING.
74	2.89	96.93
100	4.00	92.93
200	23.60	69.40
PAN	69.51	0.0
TOTAL	100.00	——

Sand.

In making up the synthetical or artifically graded sands, two different sands which will be designated as No. 1 and No. 2 were used. Sizes larger than 0.2 of an inch were screened out, and a mechanical analysis for the remaining material was made. The percentages of the various sizes are given in Table 4 , and the curves with the cement added in the ratio 1 : 3 are shown in Plate I. Sand No. 1 was taken from the Wabash River, Indiana. It was a clean sand of uniform structure, well graded, but with

an abundance of coarse material. The Specific Gravity was found to be 2.64 . No. 2 was a local sand; it was a very fine sand as will be observed from the table above referred to. This sand was also of a uniform composition, being very similar to the Wabash sand. The reason for using both sands in making the synthetical sand was that it was found impossible to obtain enough fine material in the Wabash sand.

Natural Sands.

Tests were made on both sands described above in their natural grading, and also on three other sands. Sand No. 3 was a Mississippi River bar sand obtained near Port Byron, Illinois. This sand was very clean and sharp, and of a very uniform composition, pure quartz forming a large part of the sand. There was an absence of coarse particles in this sand as will be noticed from Table 4. The specific gravity was 2.61 . Sand No. 4 was a bank sand obtained from a pit known as Charley's Pit, situated on the Bluff, about 3 miles south of the Illinois River at La Salle, Illinois. This sand contained considerable coarse material as will be seen from Table 4. It was of glacial origin, uniform in composition, and had a specific gravity of 2.64 . Sand No. 5 was a bar sand taken from the Vermillion River at Deer Park, Illinois. The composition was not very uniform as it contained some foreign material, such as clay and shale. The specific gravity was found to be 2.63 .

Screening.

Standard sieves were used to screen the sand into thirteen sizes. A motor-driven sifting machine was utilized to sift the large amount of sand required. By running the machine a given length of time, and using the same amount of sand in each charge, uniform sifting was obtained.

TABLE 3
SHOWING
THE
SIZES OF SIEVES

COMMERCIAL NO.	DIAMETER PARTICLE PASSING SIEVE INCHES
2	.2
5	.16
8	.10
10	.075
16	.046
20	.034
30	.020
40	.016
60	.014
74	.0071
100	.0058
150	.0036
200	.0027

DESCRIPTION OF CURVES.

Ellipse.

A curve was desired for investigation which would consist of a straight line and an ellipse. The ellipse was so chosen that it was tangent to the straight line through the intersection of the 100 percent abscissa and the ordinate representing the maximum size used, at a point corresponding to 1/8 the maximum size, and passing through the point $x = .0027$, $y = 23$. The general equation for an ellipse referred to zero coordinates is $y = \frac{b}{a}\sqrt{2ax - x^2}$. By assuming $a = .025$, $b = 20$, $\frac{b}{a} = 800$, an ellipse was found which fulfilled the conditions when it was shifted upward along the vertical axis until the starting point had the coordinates $x = 0$ $y = 14$. The percentage of material retained on the sieve corresponding to any particular abscissa representing the diameter, was found by subtracting the value of the ordinate at that point, from the value of the next succeeding ordinate. These percentages were tabulated opposite the corresponding sizes of sand and cement. From the mechanical analysis of the cement, the percent retained for any given size was found. The cement entered into the total mixture in the ratio 1 : 3 . The deficiency or difference between the total percent required as determined from the curve, and the percent furnished by the cement for any particular size, was furnished by the sand.

Parabola.

A parabola was chosen which would lie in the neighborhood of the ellipse previously described. The general equation of a parabola is $y^2 = k x$. In order to fulfill the conditions above referred to, it was found necessary to make the curve pass through the point $x = 0$ $y = 10$ and $x = 0.2$ $y = 100$. The equation then becomes $(y - 10)^2 = 40500 x$, the value of k being found to be 40500. The percentages of the different sizes of sand and cement for this and the two remaining curves were found as explained in the case of ellipse.

Curve No. 2.

Curve No. 2 was chosen in such a way as to obtain a mortar which would contain an excess of fine material, and be deficient in the coarse sizes.

Curve No. 4.

The mortar made according to curve No. 4 contains no very fine material except that supplied by the cement. Only four sizes of sand, namely the four coarsest, were used in order to have a mortar deficient in fine material.

VOLUMETRIC TESTS.

A volumetric test is the determination of the actual volume of a material. For example the actual volume of sand is the difference between the observed volume and the volume of voids or air spaces in the sand. For each of the four synthetical sands and for the five natural sands, a volumetric test of the mixture used, was made. The tests were made according to the general principles laid down by the French Commission in 1894 and the volumes calculated by methods used by M. R. Feret, the eminent French investigator.

Apparatus.

The apparatus used consisted of the following: 2 - 500 c.c. graduates, cylindrical ramming stick one inch in diameter and 16 inches long, trowel, wire brush and a Harvey Balance.

Weighing.

All materials were proportioned by dry weight. The Harvey balance was used to weigh out the sand and cement for the test. The required amount of the variuos sizes of sand obtained from the schedule of weights in Tables 5 to 8 were weighed out beginning with the coarsest size. At the last the full amount of cement was added. The cement was added directly from the sack, it being assumed that it conformed to the mechanical analysis given in Table 2.

Mixing.

The sand and cement were thoroughly mixed with a trowel before the water was added. Owing to a variation in the sizes of sand, no definite percentage of water for securing a uniform consistency of mortar could be selected in advance for each mix. The pan containing the sand and cement, together with the trowel and ramming rod, was placed on the scales and weighed. Water was then added to the sand and cement from a graduate, the quantity originally contained being recorded, until a mortar of mushy consistency was obtained. Practically the entire amount of this mortar was then introduced into a graduate in five equal increments, each being thoroughly rammed. The pan, trowel, and rammer were next weighed to determine the weight of the mortar used, and a reading was taken on the graduate containing the water to determine the amount of water used. After 20 minutes had elapsed the volume of water in the graduate and the amount of free water were obtained by taking readings on the outside of the graduates.

COMPRESSION TESTS.

Three 3-inch cubes constituted a set for the compression test on each sand. Duplicate tests were made on each of the synthetical sands. The results of the compression tests are given in Tables 10 and 11 .

Forms.

The forms consisted of two channels placed 3 inches apart back to back. Plates 1/8 inch in thickness were inserted in grooves cut in the back of the channels so that the clear distance between plates was 3 inches. Four bolts with hexagonal nuts, two outside of each end plate, held the form together rigidly.

Weighing and Mixing Material.

The remarks made on this subject under the head of "Density Tests" apply here, except that the required amount of water was known in advance from the density test. The time required in mixing the mortar was made the same in each test.

Placing in Forms.

The mortar after being thoroughly mixed was placed in the forms in four equal increments. Each increment received constant ramming with a cylindrical stick 1 inch in diameter. The top was then smoothed off with a trowel.

Storing.

The cubes were covered with a moist cloth and allowed to stand for 24 hours in the forms. At the expiration of that time the cubes were removed from the forms and placed in a tank of water where they remained till they were to be broken.

Breaking.

The cubes were removed from the water and allowed to stand in the air for 30 minutes. The top and bottom faces were then bedded in plaster of Paris which was allowed to set for 20 minutes. The cubes were then placed in a 100 000 pound Riehle testing machine and tested to failure.

TENSION TESTS.

Standard briquette forms as recommended by the American Society of Testing Materials were used in the tension tests. Six briquettes constituted a test and duplicate tests were made on each of the synthetical sands.

Weighing and Mixing.

The remarks made in detail on this subject under the head of "Compression Tests" apply here also, as there was no variation in the method used.

Placing in Forms.

The mortar was placed in the forms in four equal increments and rammed with the thumbs. The top was smoothed off with a trowel.

Storing .

The briquettes were kept moist and allowed to remain in the forms for 24 hours. At the expiration of that time they were removed to a storage tank and kept in water till they were to be tested.

Breaking.

The briquettes were ruptured in a Riehle automatic briquette testing machine.

CONCLUSION.

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Graded Sands.

In Table 9 are shown the averages of the density and in Table 11 the results of the breaking tests of the mixtures of cement and different artifically graded sands. As will be observed from the tables., mortar made according to the ellipse had the least percent of voids and the greatest breaking strength in both the tension and compression tests. Mortar made according to the parabola gave results very close to the ellipse in regard to the density, the parabola grading being slightly less dense. The mortar did not prove to be as strong as that made according to the ellipse. Mortar made according to curve No. 4 , in which there was a deficiency of fine and intermediate sizes, contained slightly more voids than for either of the two above described, and the tension and compression tests showed that the mortar was weaker than with either of them. Mortar made according to curve No. 2 with the coarse sizes left out contained the largest percent of voids, and the tension and compression tests showed that it was the weakest mortar of the group. In general it may be stated that the results agree with those formulated by Fuller and Thompson in regard to concrete in all particulars, as the strongest and densest mortar gave for its mechanical analysis a combination ellipse - straight line curve. In every case the strength was found to vary with the density. The results agreed with the first three formulated by

Mr. R. Feret as given in the introduction to this thesis. No statement can be made as to the fourth conclusion, as no curve of that character was investigated.

Natural Sands.

Table 9 gives the average of the density and Table 10 the results of the tension and compression tests of the mixtures of cement and natural sands. It is a difficult matter to draw any conclusion similar to those given above, for the mixtures of cement and natural sands, since the character of the sand is different in each case. Old specifications for sand usually stated that the sand should be clean, sharp and coarse. As will be seem from the tables, the two well graded sands No. 1 and No. 4, containing considerable coarse material, had the smallest percent of voids and developed the greatest strength in both tension and compression. They were both very clean sands, but neither could be classed as a sharpe sand. Sand No. 3 stood next lowest in the percent of voids, but it gave the weakest mortar of the group, this fact being due in all probability to the sand being very uniform in size and also very fine. The sand was very clean and sharp however. Sands No. 4 and 5 contained the largest percent of voids, and the ultimate strength proved to be the weakest, as was to be expected, from the statements made above.

The results of all the tests above described indicate that the densest mixture developed the greatest strength, which fact agrees with the conclusion of Messrs. Fuller and Thompson in regard to concrete.

TABLE 4

SHOWING THE PERCENTAGE OF THE VARIOUS SIZES OF 1-3 MIXTURES OF NATURAL SAND AND PORTLAND CEMENT RETAINED ON CORRESPONDING SIEVES.

SIEVE	SAND.				
	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5
	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT
P 200	17.83	19.61	21.05	17.89	17.64
R 200	6.09	6.91	7.55	6.00	6.11
150	1.54	6.32	1.92	1.28	2.20
100	2.56	16.40	5.78	1.46	7.16
74	1.36	7.54	3.15	.68	3.95
60	8.76	19.28	22.85	7.00	30.18
40	9.41	4.27	24.20	16.68	19.86
30	15.69	3.39	11.96	15.05	6.93
20	6.23	1.08	.91	3.43	1.13
16	17.35	7.42	.62	12.48	3.39
10	5.38	2.98	.07	5.92	.67
8	5.62	3.18	.01	6.79	.48
5	2.18	1.62	.00	5.38	.26
TOTAL	100.00	100.00	100.00	100.00	100.00

TABLE 5

SCHEDULE OF WEIGHTS FOR THE PARABOLA.

ARTIFICIALLY GRADED 1-3 MIXTURE OF CEMENT AND SAND.

SIEVE	PERCENT	PERCENT		FOR VOL. TESTS		CUBES AND BRIQUETTES.	
		CEMENT	SAND	CEMENT GMS.	SAND GMS.	CEMENT	SAND.
P200	20.45	20.45		125.0		1000.0	
R200	1.81	1.81					
150	3.04	1.01	2.03		10.15		81.2
100	1.65	1.00	.65		3.25		26.0
74	6.85	.73	6.12		30.60		244.8
60	1.66		1.66		8.30		66.4
40	2.96		2.96		14.80		118.4
30	8.58		8.58		42.90		343.2
20	6.20		6.20		31.00		248.0
16	12.00		12.00		60.00		480.0
10	8.40		8.40		42.00		336.0
8	19.20		19.20		96.00		768.0
5	7.20		7.20		36.00		288.0
TOTAL	100.00	25.00	75.00	125.0	375.00	1000.0	3000.0

TABLE 6

SCHEDULE OF WEIGHTS FOR CURVE NO. 2
ARTIFICIALLY GRADED 1-3 MIXTURE OF CEMENT AND SAND.

SIEVE	PERCENT	PERCENT		FOR VOL. TESTS		CUBES AND BRIQUETTES	
		CEMENT	SAND	CEMENT GMS.	SAND GMS.	CEMENT GMS.	SAND GMS.
P200	20.5	18.5	2.0	125.0	10.2	1000.0	81.6
R200	4.8	4.8	0.0		0.0		0.0
150	10.7	0.0	10.7		53.5		428.0
100	18.0	1.0	17.0		84.9		679.2
74	6.0	0.7	5.3		26.4		211.2
60	2.7		2.7		13.5		108.2
40	5.3		5.3		26.5		212.0
30	6.0		6.0		30.0		240.0
20	2.1		2.1		10.5		84.0
16	13.9		13.9		69.5		556.0
10	1.9		1.9		9.5		76.0
8	4.8		4.8		24.0		102.0
5	3.3		3.3		16.5		132.0
TOTAL	100.0	25.0	75.0	125.0	375.0	1000.0	3000.0

TABLE 7.

SCHEDULE OF WEIGHTS FOR THE ELLIPSE ARTIFICIALLY GRADED 1-3 MIXTURE OF CEMENT AND SAND.

SIEVE	PERCENT	PERCENT		FOR VOL. TESTS		CUBES AND BRIQUETTES	
		CEMENT	SAND	CEMENT GMS.	SAND GMS.	CEMENT GMS.	SAND GMS.
D 200	23.02	21.97	1.05	125.0	5.25	1000.0	42.0
R 200	1.31	1.31	0.00		0.00		0.0
150	2.48	0.00	2.48		12.40		99.2
100	1.16	1.00	.16		.80		6.4
74	4.01	.72	3.29		16.45		131.6
60	.71		.71		3.55		28.4
40	1.51		1.51		7.55		60.4
30	5.30		5.30		26.50		212.0
20	4.35		4.35		21.75		174.0
16	10.45		10.45		52.25		418.0
10	9.20		9.20		46.00		368.0
8	21.80		21.80		109.00		878.0
5	14.70		14.70		73.50		588.0
TOTAL	100.00	25.00	75.00	125.0	375.0	1000.0	3000.0

TABLE 8.

SCHEDULE OF WEIGHTS FOR CURVE NO. 4.
ARTIFICIALLY GRADED 1-3 MIXTURE OF CEMENT AND SAND

SIEVE	PERCENT	PERCENT		FOR VOL. TESTS		CUBES AND BRIQUETTES	
		CEMENT	SAND	CEMENT GMS.	SAND GMS.	CEMENT GMS.	SAND GMS.
P200	17.35	17.35		125.0		1000.0	
R200	5.88	5.88					
150	0.00	0.00					
100	1.00	1.00					
74	.77	.77					
60	0.00		0.00				
40	0.00		0.00				
30	0.00		0.00				
20	0.00		0.00				
16	9.00		9.00		45.00		360.0
10	4.00		4.00		20.00		160.0
8	31.00		31.00		155.00		1240.0
5	31.00		31.00		155.00		1240.0
TOTAL	100.00	25.00	75.00	125.0	375.0	1000.0	3000.0

TABLE 9

SHOWING THE VOIDS IN 1-3 PORTLAND MORTARS AS SET.
CHICAGO A.A. PORTLAND CEMENT.

REF. NO.	NET CEMENT GMS.	NET SAND GMS.	PERCENT WATER	SP. GR. SAND	SP. GR. CEMENT	CALCULATED VOLUMES SAND C.C.	CALCULATED VOLUMES CEMENT C.C.	CALCULATED VOLUMES TOTAL C.C.	ACTUAL VOLUME MORTAR C.C.	VOLUME VOIDS CU.C.M. OF MORTAR AS SET C.C.	PERCENT VOIDS OF 1 C.C. AS SET.
1	122.1	368.1	10.6	2.64	3.15	139.5	38.90	178.4	227.0	.2140	21.40
2	122.9	368.7	16.0	2.63	"	140.0	39.00	179.0	270.0	.3370	33.70
3	121.9	365.6	12.0	2.60	"	140.5	38.70	179.2	233.5	.2330	23.30
4	121.7	365.1	11.1	2.64	"	134.5	38.60	173.1	221.0	.2164	21.64
5	121.9	365.7	11.6	2.63	"	138.0	38.60	176.6	255.0	.3080	30.80
6	121.8	365.3	10.0	2.65	"	138.0	38.65	176.6	224.0	.2115	21.15
7	121.0	363.0	13.2	2.64	"	137.3	38.40	175.7	251.0	.3000	30.00
8	120.8	362.4	9.6	2.65	"	136.8	38.38	175.2	222.0	.2105	21.05
9	123.0	369.0	8.2	2.64	"	139.9	39.10	179.0	230.4	.2220	22.20

TABLE 10

SHOWING THE RESULTS OF THE TENSION AND COMPRESSION TESTS ON 1-3 MIXTURES OF CEMENT AND NATURAL SAND.

SAND NO.	AGE DAYS	TENSILE STRENGTH			COMPRESSIVE STRENGTH				REF. NO.
		NO. BREAKS	AVERAGE LBS. PER SQ. IN.	PROBABLE ERROR	NO. BREAKS.	POUNDS PER SQUARE INCH			
						MAX.	MIN.	AVERAGE	
1	28	5	341	±5.4	3	1811	1620	1699	1
1	90	5	494	±7.1	3	3112	2777	2922	1
2	28	5	219	±9.8	3	1440	1152	1297	2
2	90	6	310	±9.1	3	1443	1358	1402	2
3	28	6	148	±7.8	3	678	444	582	3
3	90	5	232	±4.4	3	1376	1170	1252	3
4	28	5	256	±8.1	3	1841	1569	1698	4
4	90	5	452	±7.4	2	3460	3444	3452	4
5	28	6	162	±2.4	3	1548	1409	1500	5
5	90	6	208	±6.6	3	1780	1605	1712	5

TABLE II

SHOWING THE RESULTS OF THE TENSION AND COMPRESSION TESTS OF 1-3 MIXTURES OF CEMENT AND ARTIFICIALLY GRADED SANDS.

CURVE	AGE DAYS	TENSILE STRENGTH			COMPRESSIVE STRENGTH				REF. NO.
		NO. BREAKS	AVERAGE LBS. PER SQ. INCH	PROBABLE ERROR	NO. BREAKS	POUNDS PER SQUARE INCH MAX.	MIN.	AVERAGE.	
PARABOLA	28	10	328	±8.6	5	3215	2750	2960	6
"	90	10	510	±6.4	5	3999	3171	3546	6
NO.2	28	11	203	±6.9	6	1111	994	1038	7
"	90	10	336	±4.7	5	2019	1721	1870	7
ELLIPSE	28	10	421	±10.1	5	3794	3516	3694	8
"	90	10	548	±14.8	4	4302	3772	4023	8
NO.4	28	11	402	±10.6	6	2533	2143	2385	9
"	90	9	418	±7.5	5	3281	2544	2787	9

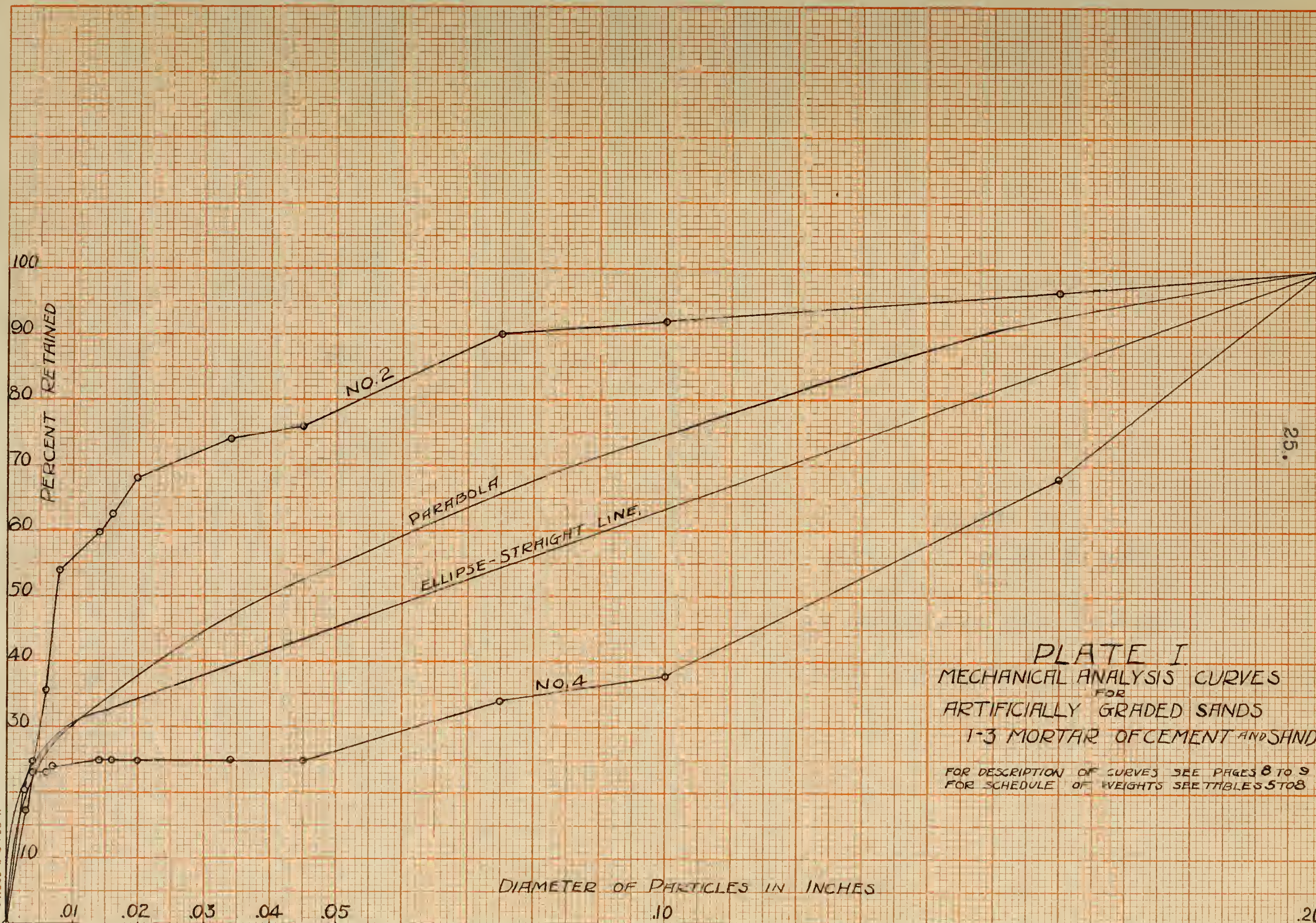

PLATE I

MECHANICAL ANALYSIS CURVES FOR ARTIFICIALLY GRADED SANDS

1-3 MORTAR OF CEMENT AND SAND

FOR DESCRIPTION OF CURVES SEE PAGES 8 TO 9

FOR SCHEDULE OF WEIGHTS SEE TABLES 5 TO 8

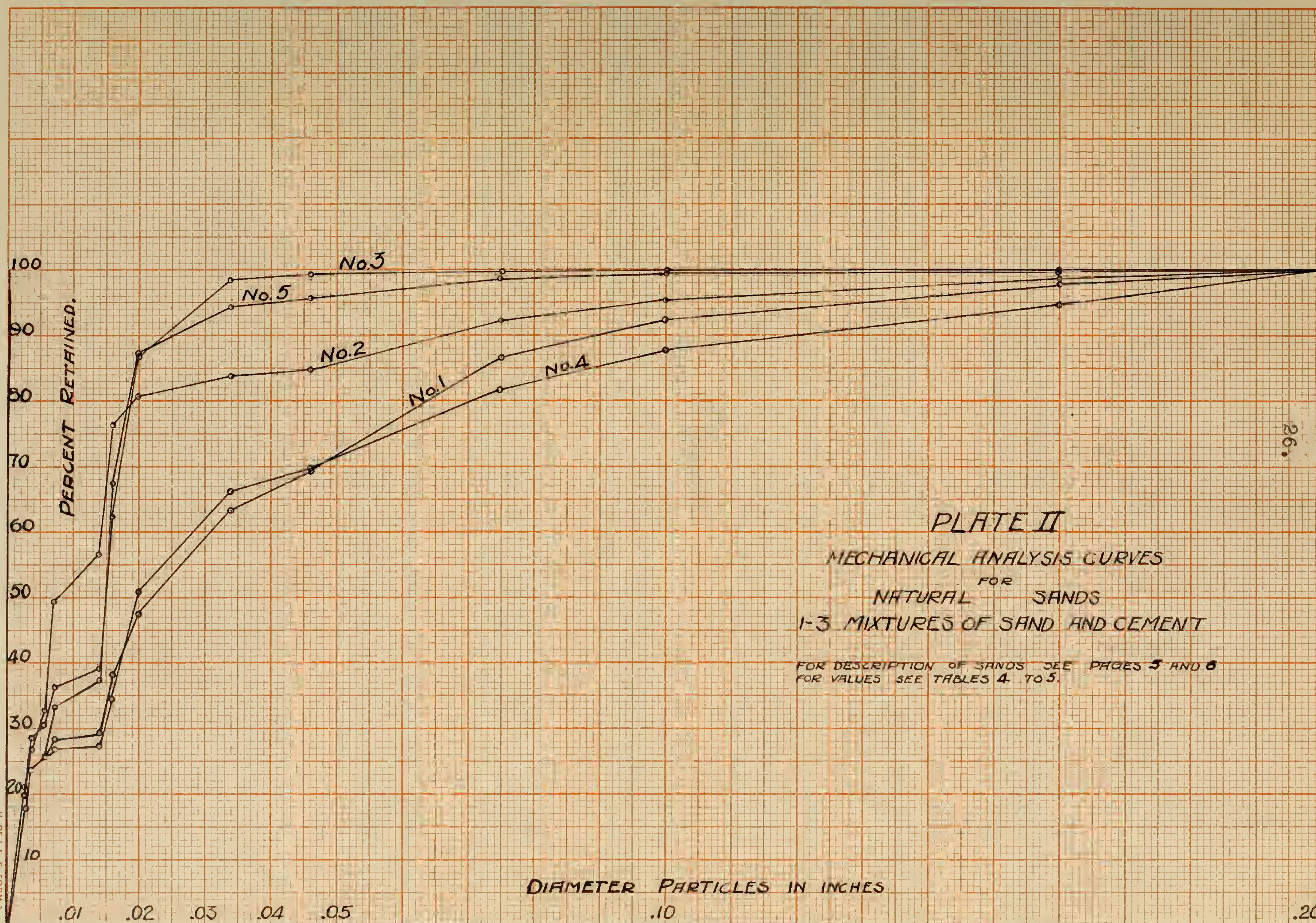
PLATE II
MECHANICAL ANALYSIS CURVES
FOR
NATURAL SANDS
1-3 MIXTURES OF SAND AND CEMENT
FOR DESCRIPTION OF SANDS SEE PAGES 5 AND 6
FOR VALUES SEE TABLES 4 TO 5.
PERCENT RETAINED.
DIAMETER PARTICLES IN INCHES
No.1
No.2
No.3
No.4
No.5
100
90
80
70
60
50
40
30
20
10
.01
.02
.03
.04
.05
.10
.20
U. OF I. S. S. FORM 3